Energy Efficient Approach to Improve the Sustainability of Wireless Sensor Networks

By

Arun Kumar
Roll No. 11108861
Regn. No. 10-Ph.D-028

Under the supervision of

Dr. V.K. Katiyar
Professor & Head
Computer Engg. Department, M.M.E.C,
M.M.U. Mullana, (Ambala)

Department of Computer Engineering
M. M. Engineering College

Maharishi Markandeshwar University, Mullana, Ambala

November 2012

November 2012

ABSTRACT

Wireless Sensor Network consist of sensors which are distributed in an Ad-Hoc network. ***Due to the limited power of sensors methods must be devised for sustaining network life.In synopsis I am planning to include approaches to increase sustainability of WSN i.e. efficiently utilizing power of sensors. In this regard one goal is to prove the importance of mobile sink. Second goal is to build application for mobile data collection and on use of mobile sink. Another goal is to work on placement of sensors for efficient power utilization. And finally fourth goal is to devise efficient routing decisions for efficient utilization of sensor power.***

INTRODUCTION

Computer Networks are vital for communicating and sharing resources among users of computers, mobile devices and embedded systems.

In a Wireless Sensor Network the sensors are distributed randomly in a wide monitoring area which form a wireless ad-hoc network which can be classified according to its topology into static or dynamic. In a static configuration all the sensors, sinks and base station are deployed and they maintain fixed positions. Whereas in a dynamic configuration, the sensors and sinks may change their location.

The main characteristics of a Wireless Sensor Network are [3] :

Ad-hoc: Just like in a traditional Mobile Ad-Hoc Network, in a Wireless Sensor Network the network is built at the time the sensors are deployed in the field. There is no centralized infrastructure that manages the network. All the nodes that become part of the network use adaptive protocols that let them recognize and communicate with their immediate neighbors in range. Communication to distant nodes is done using multi-hop transmission. This characteristic of the Wireless Sensor Networks provides an easy and fast development.

Very densely populated: Distinct from other wireless networks, a Wireless Sensor Network requires that a large number of sensors is deployed in small areas. One reason of using a large

number of sensors is to provide redundancy in case some nodes die prematurely because of early depletion of energy or physical damage. This will ensure that the information read by the sensors reach the sink. Another reason is that if some nodes fail, then a densely populated Wireless Sensor Network will prevent the occurrence of network holes where no data can be read, or network partitions where data cannot be transmitted to the sink.

Limited power and limited resources: This is a special characteristic of Wireless Sensor Networks. The nodes have a limited source of energy (usually battery powered). Once this source of energy is depleted, nodes become useless, they cannot acquire or transmit data. In most applications, it is impractical to replace this power source, because of accessibility conditions and because usually a large number of nodes are deployed. Sensor nodes have limited transmission range, typically few hundred feet, and low CPU processing power.

Scalability: One important characteristic of a Wireless Sensor Network is that it should be able to easily handle large number of nodes in the network and to allow the incorporation of new ones in a faster and easy way. Since Wireless Sensor Networks have large number of sensor nodes, it becomes too costly and impractical to maintain unique node identifiers [3].

Mobility: In mobile Wireless Sensor Networks, similar to MANETs, the nodes or other components such as the sink may be mobile. In WSNs because of limited power supply and resources, different types of dynamic topologies and protocols are used.

One of the main issues in WSNs is the conservation of energy on the sensors in order to maximize the lifetime of the whole network. The sensors are usually powered by a limited source of energy, and when the energy source (e.g. batteries) is depleted, it usually cannot be replaced. In a typically WSN configuration, sensors send data to the sink (or base station) using direct transmission or multi-hop communication. In a static configuration sensors that are located near the sinks are the first ones that suffer from energy depletion. The reason is that those sensors also relay data from other sensors to the sink. This situation causes an unbalanced energy consumption, where sensors near the sinks die first and as a result, network partitions can occurs. Therefore, because of the uneven use of energy the WSN lifetime is reduced. For making a WSN, it is necessary to put the sensors and devise routing protocols in a way to continue with connectivity and keeping the network lifetime to maximum.

We will devise different routing protocols and techniques for the movement of sinks to areas where sensors have high energy to effectively extend the life time of the network.

LITERATURE SURVEY

Networks can be classified depending on the transmission medium. In this regard, there are two main types, wired and wireless networks.

In wired networks, the computers are interconnected using cables such twisted pair cables, coaxial cables or fiber optics. One of the most popular and of general use wired networks technology is the Ethernet. The Ethernet has its standard defined for Physical Layer, Data Link Layer and Medium Access Control (MAC) in IEEE 802.3[1].

Wireless networks on the other hand use the air and space as a medium of connection and transmission between devices. Today the most common types of wireless networks use of one of the following technologies: microwaves, satellite signal, cellular radio, Bluetooth and Wireless LAN. The Wireless LAN standard is defined in the IEEE 802.11 standard and its amendments [2].

Wireless Sensor Networks

A Mobile Ad-hoc NETwork (MANET) is a decentralized wireless network that does not depend on a pre-build infrastructure. Every device which is part of the network, acts as a router and therefore participates in forwarding data between a source and a destination. In this way, two nodes can communicate with each other even if they are not in range. In a MANET, a node may have mobile capabilities and it can move in or out of the network.

The main characteristic of a MANET is that devices can quickly and easily form a temporary network. A good example on the practicality of a MANET is mentioned in [3] where a rapid response is needed. In the case of disaster, emergency teams could easily form a MANET with portable computers and handheld devices. MANET can provide an easy and fast deployment, self-organization and strength.

A WSN is a specific type of ad-hoc wireless network which is composed of densely deployed small electronic devices, usually powered by a limited source of energy (e.g. batteries), that have sensing, storage, processing, and communication capabilities. The main purpose of the network is to interact with the physical environment, detect a specific occurrence of a phenomenon, storage, process and send the information to a pre-determinate destination. In WSNs all the devices form a cooperative entity in which local information provided by each sensor is gathered in order to get an overall information about the area that is the target of the monitoring or surveillance process.

Literature on WSNs [3], relate MANETs and WSNs as being very close. Both networks initialize at the deployment time, so there is no centralized infrastructure that manage the network as a whole. Each node can communicate with other ones that are in range using direct transmission and with nodes father away using multi-hop transmission. The implementation is also easy and fast. As soon as the nodes of the WSN are deployed, the network is formed and starts working.

Figure 1 presents the main components of a WSN. Sensor nodes are deployed in the monitoring field, they sense the environment and transmit data to a sink. Each sensor also act as a router, and participate in data forwarding. The user can access the data from the sink directly or through a network.

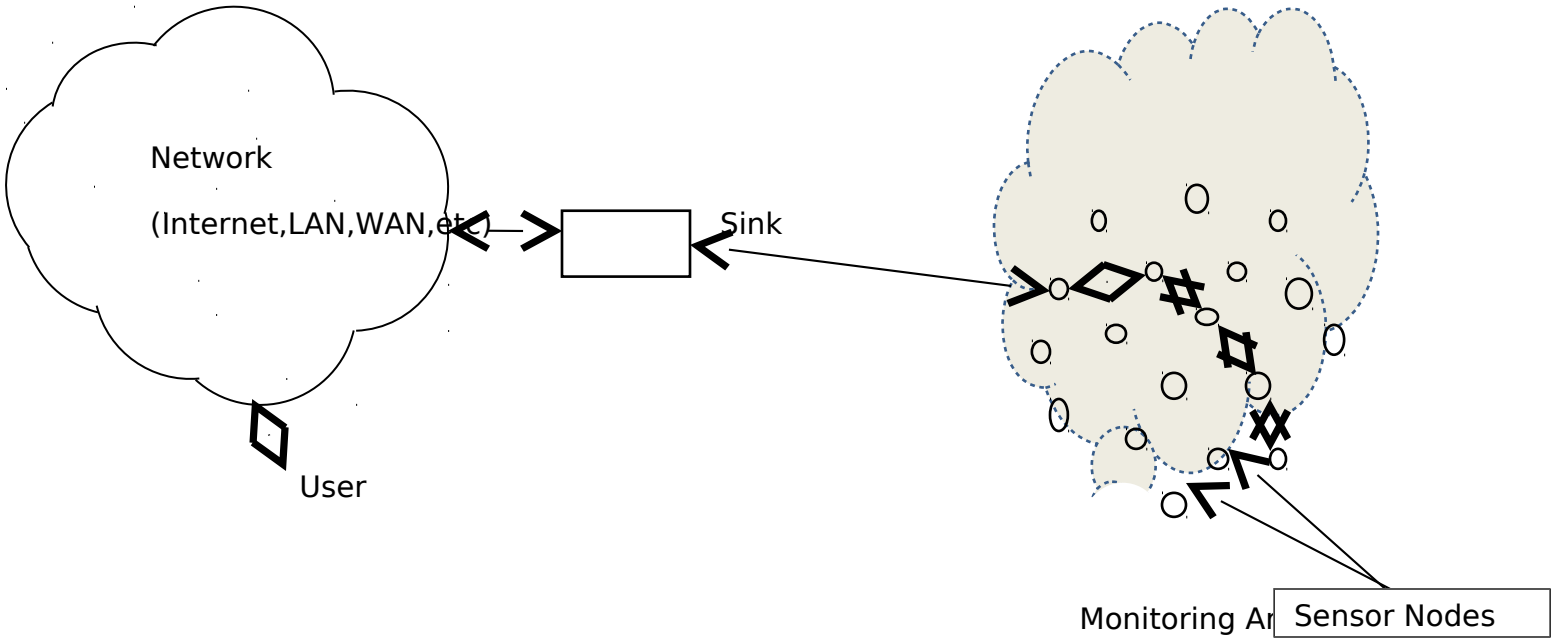

Figure 1: *Sensors arrangement in a WSN. Nodes utilizing multi-hop communication and end user access the data through a network*

In WSNs most of the nodes have limited power resources and are designed to handle one type of application. In a WSN, sensors are densely deployed in a specific area and due to the large number of nodes (perhaps hundred or thousands) the nodes usually do not have a unique identifier (e.g. MAC address, or IP address). WSNs also are more prone to failures due to the interaction with the environment, physical damage and depletion of energy resources. The typical components of a sensor node [3] are shown in Figure 2:

Power Supply: This component provides the necessary energy source to all the components in the node. In most WSNs the power supply consists of one or two batteries. The type of battery varies according to the technologies. This is an important component since the lifetime of the

sensor node depends on it. In some modern sensor nodes, this power supply is self-rechargeable, with the use of solar panels or kinetics sources, but this considerably increases the cost of the node.

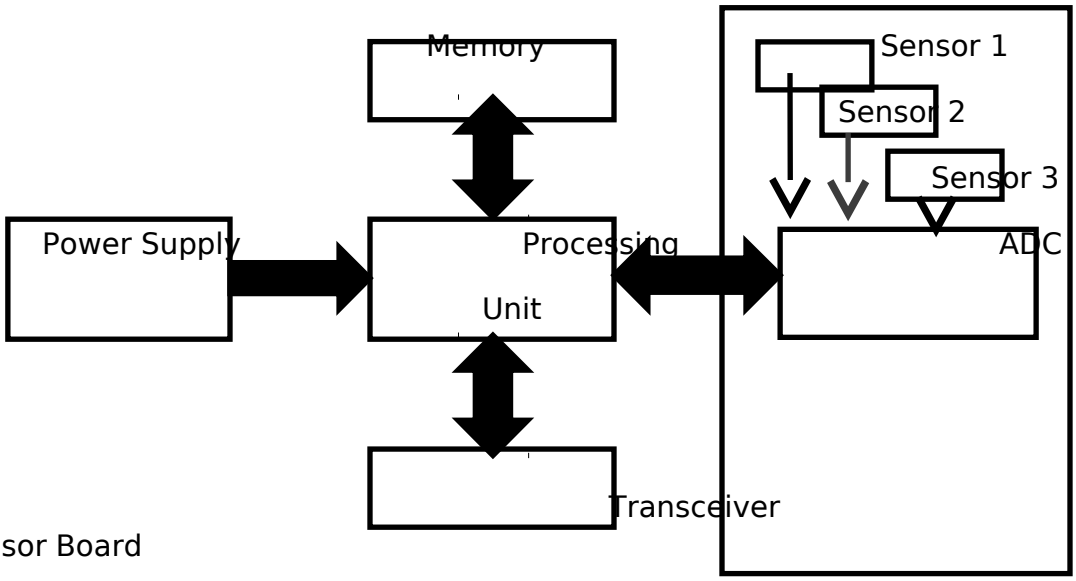

Figure 2: *Sensor node components diagram*

There are mainly these issues in a WSN : Security, Data Logging, Limited Network Lifetime, Node Redundancy, Network Holes, Network Partitions, Localization and Congestion Control.

Security deals with attacks on WSN which come from all directions and target any node leading to leaking of secret information and interfering messages [15].

Even though the sensors collect a vast amount of data, only a tiny fraction of this data may be useful. A data-logging & supervisory control architecture manages the information gathered by the WSN and make decisions based on this information [16].

In WSNs, one of the most important issue is how, when, and for how long the data acquired by the sensors is processed and sent to the sink. In this regard, data collection protocols must accomplish a reliable data transmission, and must be energy-efficient in order to extend the lifetime of the network. The simplest method is Direct Transmission [1] where each node acquires the data and sends it directly to the sink. This method is very inefficient with regard to data collection (since interference and collisions will occur) and power management of the nodes. If nodes are randomly placed, then the nodes farther away from the sink will die first, because the power to transmit will be greater than that of the sensors near the sink. There is a need to design protocols and algorithms that find a balanced solution to these three issues.

Low Energy Adaptive Clustering Hierarchy - LEACH [4]

LEACH is a protocol designed for WSNs, that provides efficient data gathering and energy consumption. The protocol uses cluster-heads to gather data of the surrounding nodes and to send it to the base station. There are two phases, the setup phase when the cluster-heads are chosen and the steady phase, when all the nodes transmit data and the cluster-heads are maintained. In LEACH, an algorithm is used to elect the cluster-heads in each round, such that a cluster-head node will not be repeated in consecutive rounds. The protocol is energy-efficient since the role of cluster-head is rotated among all the nodes in the network. There is also a variation in LEACH that allows the algorithm to chose a cluster-head among all the nodes that have predetermined energy threshold. Results show a 30% increase in network lifetime when using the energy threshold method compared to the direct data transmission mechanism.

Power-Efficient Gathering in Sensor Information Systems – PEGASIS [5]

PEGASIS is another protocol used in WSN. It is an improvement over LEACH. It assumes that each node communicates with the closest neighbors. All nodes take turns to transmit data to the sink. Nodes form a chain and each node gathers and fusions the data received from a neighbor and then passes the information to the other neighbor. Once the data reaches the leader in the chain, the data is sent to the sink. Similar to the LEACH mechanism, the leader in the chain is chosen in each round randomly. This allows a more distributed use of energy in each node. At the same time, nodes die randomly and this increases the robustness to failure of the network. PEGASIS can accomplish 100% better performance compared to LEACH and it also balances the energy dissipation in all the nodes in the network.

SpaseLoc method is used for estimating moving sensors locations i.e. for solving the problem of localization [17].

Congestion control is of great importance. It can reduce the delay and save precious energy by regulating the transmitting rates, or by provisioning additional resources (e.g wake up nodes) [18].

AODV is a reactive routing protocol which uses traditional routing tables, one entry per destination [19].

Dynamic Source Routing (DSR) protocol is perticularly designed for multi-hop ad hoc networks. The difference between DSR and other routing protocols is that DSR uses source routing

supplied by packet's originator node to determine packet's path on the network whereas others relies on independent hop-by-hop routing decisions made by each node [19].

Using mobile sinks for data collection is an important mechanism. Sensor are battery powered, therefore they have limited lifetime. When sensors consume all available source of energy they start to die and this causes energy holes and partitions in the WSN. When a mobile sink is used, sensors can conserve their energy longer, and depending on how the mobile sink moves across the network, a balanced energy consumption can be accomplished.

Another mechanism proposed to deal with energy efficiency is putting sensor nodes to sleep.

In [6], authors provide a classification and comparison of different approaches. The authors classify the mechanisms into three categories according to the use of mobility:

- Using mobile sinks
- Using mobile redeployment
- Using mobile relays

In case that sensor nodes are randomly deployed and static, the nodes that are located near the sink consume more energy due to the additional load of forwarding packets on behalf of the other nodes located farther away. It is desirable to have a balanced load of energy consumption for all the nodes in the network in order to extend network lifetime. Several authors [7], [8] and [9], proposed a mix of static and mobile nodes. The mobile nodes have more computational and energy resources. They can move to the areas where those resources are needed.

Lui and Ssu [9] mention the use of a non-uniform deployment of nodes under the assumption that every node knows its own location, the position of the sink, the total number of nodes in the network, and the mobile capability. Nodes use multi-hop communication to relay data to other nodes, choosing the ones closest to the sink as the next hop.

The strategies in [9] and [10] are the implementation of algorithms that determine the density of nodes in different regions of the networks.

In the case of mobile sinks, the issues presented in [11] are mainly related to the trajectory that the mobile sinks must follow.

OBJECTIVES :

1. Formulating a strategy to use mobile sinks for data collection in WSNs to conserve energy and proof of the concept.
2. Development of the software to interconnect platforms to gather the sensor data and to build the mobile sink application.
3. Network lifetime extension by efficient placement of sensors.
4. Optimal use of sensor power by devising methods for making efficient routing decisions to distribute the energy consumption of the network.

REFERENCES:

1. [IEEE2008] IEEE Standards Association, “IEEE 802.3: LAN/MAN CSMA/CDE (Ethernet) access method”, 2008. http://standards.ieee.org/getieee802/802.3.html.
2. [IEEE2007] IEEE Standards Association, “IEEE 802.3: LAN/MAN wireless LANs”, 2007. http://standards.ieee.org/getieee802/802.11.html
3. [Holger2005] K. Holger, and A. Williq,”Protocols and Arquitectures for Wireless Sensor Networks”, Souther Gate, Chichester: John Wiley & Sons Ltd., 2005.
4. [Heinzelam2000] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “Energy-Efficient Communication Protocol for Wireless Microsensor Networks”, HICS 2000.
5. [Lindsey2002] C. S. Raghavendra, S. Lindsey, "PEGASIS: Power Efficient GAthering in Sensor Information Systems“, 2002 IEEE Aerospace Conference, March 2002.
6. [Yinying2009] Y.Yinying, M.Fonoage, and M. Cardei. "Improving Network Lifetime with Mobile Wireless Sensor Network", Computer Communications, 2009: 409-414.
7. [Mirela2008] M. Mirela, and M. Cardei. "Using Sink Mobility to Increase Wireless Sensor Networks Lifetime”, IEEE, 2008.
8. [Saamaja2010] V. Saamaja, K.K. Rachuri, and C.S.Ram Murthy. "Using Mobile Data Collector to improve Network Lifetime of Wireless Sensor Networks with Realiablity Constraints", J. Parallel and Distibuted Computing, 2010: 1-12.
9. [Liu2008] C.Liu and K.Ssu. “A moving algorithm for non-uniform deployment in mobile sensor networks”. International Conference On Mobile Technology, Applications, And Systems, ACM,2008.
10. [Cardei2008] M. Cardei, Y. Yang, J. Wu, “Non-uniform sensor deployment in mobile wireless sensor networks”, in: The IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks, (WoWMoM’08), June, 2008.
11. [Aioffi] W. Aioffi M, G.R. Mateus, and F. P. Quintao. "Optimization issues and Algorithms for Wireless Sensor Networks with Mobile Sink" ACM 2003.
12. [Crossbow] Crossbow MICA2 Datasheet.
13. [Heinzelman2000] W.R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, ”Energy-Efficient Communication Protocol for Wireless Microsensor Networks”, Massachusetts Institute of Technology Cambridge, Proceedings of the 33rd Hawaii International Conference on System Sciences – 2000.
14. [Seok2003] K. H. Seok, T. F. Abdelzaher, and W. H. Kwon. "Minimun-Enegy Asynchronous Dissemination to Mobile Sinks in Wireless Sensor Networks", SenSys' 03.
15. [Hiren2006] Hiren Kumar Dev Sharma, Ajit Kumar, Sikkim Manipal Institute of Technology ‘security threats in wireless sensor networks’ IEEE 2006.
16. Aditya N. Das, Dan O. Popa, Prasanna Ballal and Frank L. Lewis “Data-Logging and Supervisory Control in Wireless Sensor Networks” International Journal of Wireless and Mobile Computing.
17. Y. Shang, W. Ruml, Y. Zhang, and M. Fromherz. “Localization from mere connectivity” MobiHoc 2003, Anapolis, MD, June 2003, ACM Press.
18. J. Kang, Y. Zhang, and B. Nath, “Accurate and energy-efficient congestion level measurement in ad hoc networks”, In Proceedings of IEEE WCNC, Mar. 2005.

19. K. Akkaya and M. Younis, “A survey on routing protocols for wireless sensor networks,” Department of Computer Science and Electrical Engineering, University of Maryland, Baltimore, Baltimore, U.S.A, 2003.